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MINISTRY OF SUPPLY

# ARMAMENT RESEARCH ESTABLISHMENT

SYMPOSIUM

ON

THE PHYSICAL EFFECTS OF ATOMIC WEAPONS

PAPER No. 10

Observations of the Delayed Gamma Radiation as a  
function of time in Tests ABLE and BAKER at BIKINI

J. L. Tuck

*AVIA 65*

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Observations of the Delayed Gamma Radiation  
as a Function of Time in Tests ABLE and BAKER at BIKINI

J.L. Tuck

Summary

The intensity of gamma radiation in tests Able and Baker was measured by an ionization chamber recording equipment over the period from one second to several hours after the explosion and at several points throughout the ship array.

In the air shot the gamma rays came as an intense burst falling off at a rate such that half the total dose was received in the first second. This observed variation of gamma ray intensity is roughly compatible with a hypothesis that most of the fission products stay in the ball of fire, emitting delayed gamma rays at the rate observed in the laboratory. Intensity after the first minute was small on account of the low residual contamination.

In the underwater shot the initial burst of intensity was negligible, the main part of the dose being received during the sustained rise of intensity attributable to the return of fission products to the vicinity of the ships as rain and mist. In this case the time to half dose was from 8 to 20 minutes. A high degree of local contamination was produced.

Estimates of gamma dose were found to agree with independent estimates made by the radiological group from similarly located films.

Tactically the dosage rates are such that, in an ABLE type attack, exposed personnel could benefit by prompt dodging behind a shield while, in a BAKER type attack, personnel would have ample time to take cover; ships with steam up could reduce the dose by moving away.

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## Introduction

Our knowledge of the gamma ray phenomenon associated with atomic bombs showed some gaps and some contradictions when the Able and Baker shots were being planned. It was decided, therefore, to supplement the usual gamma ray film measurements at the Crossroads operation with gamma ray time measurements. The purpose of these latter was to give information on the contribution to the gamma ray dose from such various factors as (1) direct radiation from the fission product cloud, (2) ship contamination, (3) water-borne contamination, (4) wind-borne contamination. Information would also be obtained on the possibility of taking evasive action from the radiation and, should the local contamination be strong, the time record might supply a key to the interpretation of the film records.

## Experimental

### 1. General

An experiment of this kind requiring measurement of a time varying quantity on a number of isolated and widely distributed ships seems to fall into two patterns involving either the large effort with gamma ray detection on the ships and radio transmission of data to a remote recording station achieving perhaps microsecond resolving power, or the smaller effort with rather simple completely self contained recording units, necessarily battery operated, of more modest performance.

Time for preparation was such that strict simplification of even the second procedure was necessary. Requirements were set at:-

- (1) No film recording, because of risk of fogging.
- (2) Apparatus not primarily dependant on triggering by radio signal.
- (3) Apparatus capable of remaining in a receptive state for several days in order to be able to tolerate a postponement of firing day without reservicing.
- (4) Protection from blast, ship motion and tropical humidity.
- (5) Ability to record a wide range of gamma intensities.

The resulting apparatus, illustrated in Fig.2, is in essence an ionization chamber which, via an amplifier, activates in a manner proportional to the logarithm of the gamma ray intensity the pen of a recorder which writes in ink on a chart driven by clockwork. The chart is advanced at the slow rate of 1/10 inch per minute with enough chart to run for 7 days. In its final form a radio triggering equipment introduced a 60 fold improvement in resolving power without sacrificing reliability, by actuating a change speed mechanism increasing the chart speed to 6 inches per minute and giving a total running time of 3 or 4 hours. The equipment was enclosed in an airtight Dural drum and mountable by a single point suspension.

### 2. The Chamber

These were of a type designed for electron collection. They had a 3 inch diameter 12 inch long brass tubular envelope and a 15 mil central wire electrode passing through hermetic seals with guard rings. The chambers were filled to a total pressure of 3 atmospheres with argon + 2% CO<sub>2</sub>. These chambers were found to be very reliable and similar in their properties, doubtless on account of the long experience



and production methods used in their manufacture. High tension supply at 2,000 V was supplied from a specially made compact dry battery (W3). The electrical properties of the chambers are described more fully in Figs. 3, 4, and 5 and under "calibration".

### 3. The Amplifier

From calculations of the gamma ray intensities expected the maximum intensity to be recorded was set at 100,000 R/hr. and the minimum, estimated to be a safe background intensity for inspection and recovery, at 1R/hr, giving a ratio of  $10^5$ . This, together with the known chamber sensitivity, set the amplifier requirement as an input range from  $4 \cdot 10^{-10}$  A to  $4 \cdot 10^{-5}$  A with an output from 0 to 3 m.a. through a resistance of 1,400 ohms. We are indebted to Dr. R. Watts who was able to develop for this work a battery operated D.C. amplifier having very satisfactory logarithmic properties. This amplifier (Fig. 1a) consisted basically of a high insulation cathode follower (959) used in a well known circuit feeding into a two triode balanced bridge circuit which developed the required power output.

The input signal to the cathode follower consisted of the potential developed by the ionization current across the variable anode cathode resistance of a miniature triode, V32. This resistance was lowered as the input signal increased by connecting the grid of the V32 to the output of the cathode follower. The effect of this direct current negative feedback was to give an amplifier sensitivity which decreased with increasing signal input in a manner dependent on the properties of the impedance tube, its bias and the operating conditions of the 959 cathode follower. In our case, when the logarithm of the current input was plotted against the output deflection, a satisfactory S shaped curve was obtained covering an input range of 5 decades. At first the amplifier sensitivity was found to be too high for small signals and it was found possible to adjust the initial sensitivity to a convenient level by shunting the V32 impedance tube by a  $1.5 \times 10^9$  ohms. resistance.

Since the amplifier output is in terms of the logarithm of a current the amplifier could not be tested by a voltage generator and a current signal generator was therefore designed, known as the initiation chamber (Fig. 1b) which proved to be a great convenience in testing. This, consisting of a 250 V battery potentiometer and a set of high resistances, provided graduated currents in roughly equal steps of log  $i$  from 1 to  $25,000 \times 4 \times 10^{-10}$  amperes.

### 4. Recorder

It was important in selecting the recording instrument to take account of the effect of the underwater shock transmitted through the ships' structure and of the violent pitching expected due to wave and blast effects from the bomb. Of the many types of instruments recording on paper some, using electro-chemical or hot wire stylus recording methods and free from ink spilling difficulties, were not procurable in time, while others used robust potentiometric balancing, e.g. Micromax, but required alternating current main power which was not expected to be available. The greater part of the available battery space for the recorder was found to be taken up by the recorder driver stage requirements, so that economy in the power used by the recorder movement was a consideration. A high sensitivity Esterline Angus movement requiring 1 m.a. full scale proved to be too sensitive to pitching and rolling of the kind expected on shipboard. At the suggestion of the makers a restoring spring of increased stiffness was adopted in such a movement, which reduced the current sensitivity to 3 m.a. full scale and the period to 0.2 seconds. This modified movement was found by experiment to be very insensitive to the antici-



ated pitching and rolling, while the battery requirements remained within acceptable limits.

#### 5. The Can and Mounting

It proved possible to accommodate the foregoing equipment inside a cylinder of 20 inches diameter and 39 inches length. The equipment was mounted on a rack bolted to a top plate; a  $\frac{1}{8}$  inch thick dural can, fitted with clamps, was arranged to enclose the equipment and form an airtight seal with a rubber gasket at the top by a contrivance (Fig.2.) similar to the lid of some types of pressure cooker.

The suspension was formed from steel bar having a hinge allowing swinging in all directions in a horizontal plane. The direct transmission of shock down the suspension was reduced by interposing a layer of rubber between the surfaces of the hinge so that there existed no metal to metal contact between the two members across the hinge. An additional feature was the adoption of a lead strip spanning the hinge which, being flexed plastically by bonding at the hinge, provided damping. This lead link was found to have worn out in some cases after the ABLE test, showing that much oscillation energy had been absorbed.

#### 6. Radio Change Speed Control

The change speed on the clock was actuated by the movement of a small lever. This lever was retained in the slow speed position by a fine steel wire link held in tension by a spring. When the relay contacts closed in the radio unit 18 volts were applied to the steel wire which fused and allowed the lever to move over to the high speed position.

#### 7. Calibrations

Using the signal generator of Fig.1b, the current sensitivity of the amplifiers was adjusted and calibrated at 23 points covering the range  $4 \cdot 10^{-10} \text{A}$  to  $10^{-5} \text{A}$ , corresponding to an anticipated range on the chamber of 1 to 25,000 R/hr. Specimen curves for units Nos. 11 and 10 are seen in Figs. 3 and 4. In order to minimize correction for battery decline such a curve was run on each unit in its ship installations 12 hours before the shot and, when possible, a similar record was made on each unit on re-entry after the shot. After BAKER, in some cases, the background contamination on the ship made it advisable to postpone these final calibrations until the unit had been removed and returned to the laboratory ship in order to keep the dosage of the operators within the legal gamma dose of 0.1 R per day. By reference to previously prepared curves of amplifier sensitivity against time, a small correction for battery decline over the 12 hours interval between calibration and firing was applied.

#### Radiation Calibration

An accurate calibration at one intensity, 5.75 R per hour, was made on each completed unit using a 2 gram source of radium and making a direct comparison in each case with a standard Victoreon chamber mounted in a position as closely as possible coincident with the ionization chamber of the unit. The results of this showed that the chambers were, within the experimental error, alike; all variations from unit to unit, amounting to about 2%, were accountable from variations in the previously made amplifier sensitivity curves. In addition to the above a calibration was made on one unit up to 100 R/hour with 2 gm. radium and using an inverse square law method.



After Bikini we were able to make a direct calibration at gamma ray intensities up to 77,000 R/hr. The resulting R/deflection curves are shown for standard and special chambers in Figs. 3 and 4 and the decline in sensitivity of the normal chamber which was found at high intensities is plotted in Fig. 5. The special chamber development arose in the following way: As direct calibrations at high intensities were not expected to be available, calibration depended on the extrapolation from 100 R/hr. up to 100,000 R/hr. Misgivings being felt about the justification of such an extrapolation, in the time available between tests ABLE and BAKER two chambers were modified on the ship to give higher collecting fields and lower charge densities. To do this, the central 15 mil wire was replaced by a  $1\frac{1}{2}$  inch diameter cylinder and the gas pressure reduced from 3 to 1 atmospheres of  $A + 2\% CO_2$ . The plan was to install these chambers, having more linear characteristics, alongside normal chambers at selected points in test BAKER, in order to obtain a check on the calibration of the normal chambers at high intensities. The basis for the original misgivings is plainly seen to be justified from Fig. 5, in which at 77,000 R/hr. the normal chamber sensitivity is seen to have declined by a factor of 20.

However, the twin installations of normal and special chambers in test BAKER provide a convenient check on experimental accuracy as both types of chamber being calibrated, the two records obtained should yield identical intensity time curves. The extent to which this is true is seen in Fig. 7 where, on the curve for the APA 70 upper installation which is such a twin, the points from both records are seen to lie close together. Another feature of this twin record is that the effects of ship motion on the recorders must have been small since they were mounted in such a way that the two recorders would have been affected dissimilarly by rolling and pitching. Only one such twin record was obtained although two twin installations were made; the normal unit of the other pair gave no record on account of an ink failure.

#### Clock Calibration

The chart speeds of all the recorders were checked at low and high speeds and found to be within 5% of rated values except with nearly run down springs. This latter reservation does not effect any of the useful parts of the records obtained in tests ABLE and BAKER.

#### Installational

##### 1. Test ABLE

In general the plan for ABLE included installations at various distances from the target point on an E-W line up and downwind of the burst. The units were not intended to withstand the direct blast pressure from the bomb at operating distances and were, therefore, always installed in closed ship compartments. These locations were chosen to have as far as possible light and calculable screening between the unit and the bomb. In fact, the unexpected point of detonation in ABLE increased the screening in most cases, especially on the Pensacola and Negate. A deep installation, coinciding with a below deck installation on the APA 69, was intended to detect water screening effects, but this ship was sunk.

Installational data for ABLE is given in Table 1.

##### 2. Test BAKER

Profiting from the lessons of test ABLE, installations in BAKER were modified to reduce the uncertainty of screening. In the downwind APA upper locations units were placed far forward in the bows, i.e., in the part of the ship nearest to the bomb, in order to minimize screening by heavy ship machinery. Also, a deep installa-



tion was made on APA 70, as far down and as nearly vertically below the upper installation as possible, with a view to detecting water screening and water contamination effects. This latter installation, though difficult to service on BAKER minus one day on a battened down and abandoned ship, yielded an acceptable record. It would be idle to enlarge on the installations which were lost due to sinking, although it is to be regretted that neither the installation in the interior of the Nagato Turret, having 11 inches of armour screening, nor its lightly screened companion on the same ship were recovered. Installational data for BAKER are given in Table 2.

Table 1

Installational Data. Test ABLE

|                    |  |
|--------------------|--|
| Pensacola          | CA-24. Cruiser. Approximate bearing of bomb with respect to ship, 150 degrees.<br>Horizontal distance from bomb. 750 yards.<br>Upwind from bomb.<br>In compartment A-203-3L. Officers' Galley<br>Estimated screening - 2 barbettes - ~ 12 inch steel<br>Radio controlled unit                                |
| Nagato             | Heavy Battleship. Approximate bearing of bomb with respect to ship, 180 degrees.<br>Horizontal distance from bomb. 850 yards<br>Upwind from bomb.<br>In starboard side of after tower on O1 deck, frame number 190<br>Estimated screening - tower members 3 inch - 6 inch steel.<br>Radio controlled unit    |
| APA 70<br>Carteret | Troop Transport. Approximate bearing of bomb with respect to ship, 190 degrees.<br>Horizontal distance from bomb. 1,700 yards.<br>Upwind from bomb<br>In after troop berthing compartment number 1-134-1, c-2C1-L on centre line<br>Estimated screening - oblique bulkheads and pipes 1 inch - 3 inch steel. |
| APA 68             | Troop Transport. Approximate bearing of bomb with respect to ship, 90 degrees.<br>Horizontal distance from bomb, 2,000 yards<br>Downwind from bomb<br>Installation as on APA 70<br>Estimated screening - bulkheads and pipes 1 inch - 2 inch steel.  |

Table 2.

Installational Data. Test BAKER

|                      |   |
|----------------------|---|
| APA 77<br>Crittenden | Troop Transport. Bearing of bomb - not known but ahead<br>Horizontal distance from bomb, 1,700 yards.<br>Downwind from bomb<br>In forward Troop Head. 1-17-1 - A - 1021-L port side<br>Estimated screening - 1 inch - 2 inch steel<br>Radio controlled unit |
| APA 70<br>Carteret   | Troop Transport. Bearing of bomb - not known but ahead<br>Horizontal distance from bomb, 3,200 yards<br>Downwind from bomb<br>Same location as above<br>Estimated screening - 1 inch - 2 inch steel   |

Table 2 (Contd)

Installational Data. Test BAKER

Radio controlled twin unit installation  
 Also:  
 Forward GSK stores. 9 foot below water line  
 Uncontrolled unit.

Table 3.

Integrated Total Gamma Ray Dosages and Comparison with Film Results

Test ABLE

| Ship   | Pensacola | Nagato | APA 70 | APA 68 |
|--|-----------|--------|--------|--------|
| Distance from bomb in yards  | 750       | 850    | 1700   | 2000   |
| Total dose in R by integration of our I(t) curve, using theory for 0-2 sec.                    | 77        | 280    | 17.2   | 1.6    |
| Open air dose as calculated from radiological film results (Dessauer)                          | 5400      | 2900   | 130    | 27     |
| Factor: $\frac{\text{Outdoor film dose}}{\text{our dose}} = \epsilon$                          | 70        | 10     | 7.6    | 16.8   |
| Calculated screening thickness of iron for above attenuation taking 1/e thickness as 1.5 inch. | 6.5"      | 3.6"   | 3.1"   | 4.2"   |
| Approximate actual screening in inches Fe  | 12"       | 3-6"   | 1-3"   | 2-4"   |

Table 4.

Integrated Total Gamma Ray Dosages and Comparison with Film Results

Test BAKER

| Ship   | APA 77<br>Upper<br>Location | APA 70<br>Upper<br>Location | APA 70<br>Deep<br>Location |
|--|-----------------------------|-----------------------------|----------------------------|
| Distance from bomb in yards  | 1700                        | 3200                        | 3200                       |
| Total dose in R by integration of our I(t) curve. No theory and neglecting small initial burst | 90                          | 31.8                        | 12.6                       |
| Total dose from accompanying radiological films (Dessauer)                                     | -                           | 30                          | 15                         |
| Total outdoor dose in R.   | 2900                        | 90                          | 90                         |
| Outdoor dose/our dose  | 32                          | 2.8                         | 7.1                        |
| Calculated screening thickness of iron for above attenuation taking 1/e thickness as 1.5 inch  | 5 ins.                      | 1.5 ins                     | 3 ins.                     |



Table 7

|                 | 7       | 7       | 7       |
|-----------------|---------|---------|---------|
|                 | 7       | 7       | 7       |
| Approximate ... | 1-2 ... | 1-2 ... | 1-2 ... |

Table 7

1. Test #1

From the eight installations made for test #1 four records were obtained yielding the final results plotted in Fig. 6. (The missing records are accounted for as follows - two by sinking, one recorder lost by shock, one loss by battery failure). For all four recorders the firing control was successful, using the putative minus 20 second time delay which actually turned on the units at minus 3 seconds. Experimentation subsequently showed that this allowed enough time for the shot to reach full speed before detonation.

The first effecting factor in the ...

In general the records show a rapidly falling gamma ray intensity for the first twenty seconds followed in the case of the two nearer ships, by an abrupt flattening out to a decay with an approximate half life of 5 minutes. The early part of the curve shows a series of small amplitude oscillations with about the same time period as the roll of the ships. As it occurs too early to have been produced by waves, it may be due to the motion of the ships produced by the air blast. Such motion would introduce variations in gamma ray screening at various points in the oscillation.

The most important factor in calculating from these curves the screening by the ships or the structure of the ship is the screening are approximately being ...

These effects are ...

Results

2. Test #2

From the nine installations made for Test #2 four records were obtained yielding the final results plotted in Fig. 7 and 7c. (The five missing records are accounted for as follows: - two by sinking which sank before being cleared by ...)

... on Crittenden ... controls ...

... the ... 3200 yards, followed by ... below 10 R/hr. after 2 hours.

It is noteworthy that when ships were boarded four days after BAKER Day, although the gamma ray contamination level on deck was 0.25 - 0.5 R/hr. on Carteret and 1 to 1.5 R/hr. on Crittenden, immediately below deck, the gamma ray contamination was only 0.1 R/hr. or less, except where infiltration had taken place. A pool of water lodged in a depression on the deck of the Crittenden had 7 - 8 R/hr. on BAKER + 4 day.

Conclusion

By assuming that the main origin of the observed gamma radiation is the emission of delayed gammas from the fission products of the bomb, which behave as a point source rising in the ball of fire, together with a knowledge of the air absorption co-efficient of the radiation, it is possible to calculate an intensity-time curve. Such a curve was calculated for each of the four distances in test BAKER, using the results of delayed gamma measurements on fission products made in the laboratory (LA 250) and Dossauer's air absorption co-efficient obtained from the BAKER film data. In this way, four curves are obtained which agree well in slope with our experimental observations from 1 second to about 10 seconds, (curves so calculated lie from 60 to 70 per cent of the magnitude than the observed curves on account of the effect of screening by the ship). This screening is not known very well. Several attempts were made to estimate it, measuring with ruler and tape, difficulties were always encountered with highly variable absorbing objects such as pipes and winches, which could vary the result by a factor of ten.

It seems possible to go some way to avoid this difficulty by making use of the Radiological film data in the following way.

In test BAKER, by which time better liaison had become established, Radiological films were placed in coincidence with the ionisation chamber on some units. Integration of the gamma intensity - time curves obtained from such units gave total doses in good agreement with the independent measurements made by the Radiological Safety Section on the films (Table 4) so that it became clear that the two methods were giving consistent results.

Since the slopes of the theoretical intensity time curves were in good agreement with experiment over the interval 1 - 20 seconds, it was decided to trust the theory in the interval from 0 - 1 second, so that it became possible to obtain a figure for the total dose, ... by using the theory to fill in the gap from 0 - 1 second ... are seen to be less than the outdoor film doses by ... factor. This factor is taken to be the attenuation factor for the ship screening which, expressed in terms of inches of iron using a mean free path in iron of 1.5 inches, is seen to be in the region of the estimated actual ship screening. The use of the resulting attenuation factors in conjunction with the theoretical outdoor intensity-time curves is seen (Fig.9) to bring the theory into fair agreement with experiment.



In addition to the rapid fall in gamma ray intensity in the initial gamma ray burst discussed above which continues right down to very low values in the two more distant ships, there is a sudden trailing off on the nearer-in ships, at 20 seconds after detonation, to a lower rate of decay of half life about 5 minutes. The presence of this effect on the nearer-in ships and absence from the far-out ones suggests that it arises from neutron induced activities, though this hypothesis meets with a difficulty. The magnitude of this effect on the two ships appears to be in scale with the gamma ray intensity which is attenuated much more on the Pensacola (~ 7<sup>0</sup> times) than on the Nagato (~ 10 times). However, a neutron induced radiation on account of the diffusion properties of slow neutrons would not be collimated but could reach the chambers laterally, where the screening in both cases is much less. Hence, if the 5 minute decay were slow neutron induced, it would be expected to be proportionately much higher on the Pensacola unless some local vagary of distribution of the neutron capturing material introduced a compensating effect. On the whole, this neutron hypothesis seems therefore unsatisfactory and a better explanation lies in assuming a tail of gamma-emitting fission products left behind by the ball of fire on the near-in ships.

In the BAKER records (Figs. 7, 7b) the initial burst of radiation analogous to that in ABLE is quite small in magnitude. In the case of the distant Carteret at 3200 yards the intensity falls rapidly as in ABLE to a low value at 40 - 50 seconds, rises steadily to a maximum at 5 minutes and then declines slowly.

It seems straight forward to explain the rise after the first minute and subsequent decay in terms of a high local concentration of fission products brought in the descending rain and in the rolling cloud of spray which spreads out from the base of the plume. These fission products then decay and remove themselves by settling into the sea and diffusing down through the sea water.

It is interesting to speculate on the meanings of the above-and below-waterline readings on the Carteret. The two records are closely similar in the shapes and times of their recorded maxima, the below-water line record not lasting so long nor rising so high and having about half the total dosage of the upper location record. The locations are almost vertically one above the other, about 40 feet and 5 steel decks apart. There is a flat deck a few feet above the upper location, so that it would be affected by deck contamination by something like an order of magnitude more than the lower. It seems likely, therefore, that ship contamination is not the main factor in the doses, but that a large proportion of it originates from fission products in the surrounding mist and on the water surface. The slight secondary maximum, on the underwater record after the main maximum, which is absent on the upper location record, is suggestive of some downward diffusion of the fission products through the water, past the unit.

The Crittendon instrumental record (1700 yds.) obtained in BAKER gives evidence of very strong vibrations lasting about ten seconds, the pen being in rapid motion and producing a series of dots. There is a similar weaker effect on the Carteret records starting at  $\frac{1}{2}$  second. The underwater shock must have caused this and the small minimum on the Crittendon curve at  $<\frac{1}{2}$  second is probably instrumental from the same cause. There appears also a marked oscillation on this curve at 70 seconds, corresponding to the expected time of arrival of the first water wave from the explosion.

By plotting the integral of the ABLE and BAKER curves up to time  $t$  as a percentage of the total integral (Fig. 9) one obtains a curve which shows the percentage reduction in dose resulting from dodging behind a strongly absorbing shield. About half the total dose is

obtained in the first second in ABLE, so that very prompt action would be needed to reduce the dose of say 200 R at 1,500 yards in ABLE to 100 R. The strong shadow produced by the turrets on the Pensacola suggests that all round shielding is unnecessary, scattering being small.

In BAKER the time to half dose is much longer, varying from 20 minutes at 1,500 yards to seven minutes at 3,000 yards. Thus there is ample time for protective measures by ship personnel, but in this case, the radiation will be fairly isotropic, so that all-round screening would be required.

---



# FIG. 1a: CIRCUIT DIAGRAM OF GAMMA RAY RECORDER UNIT.

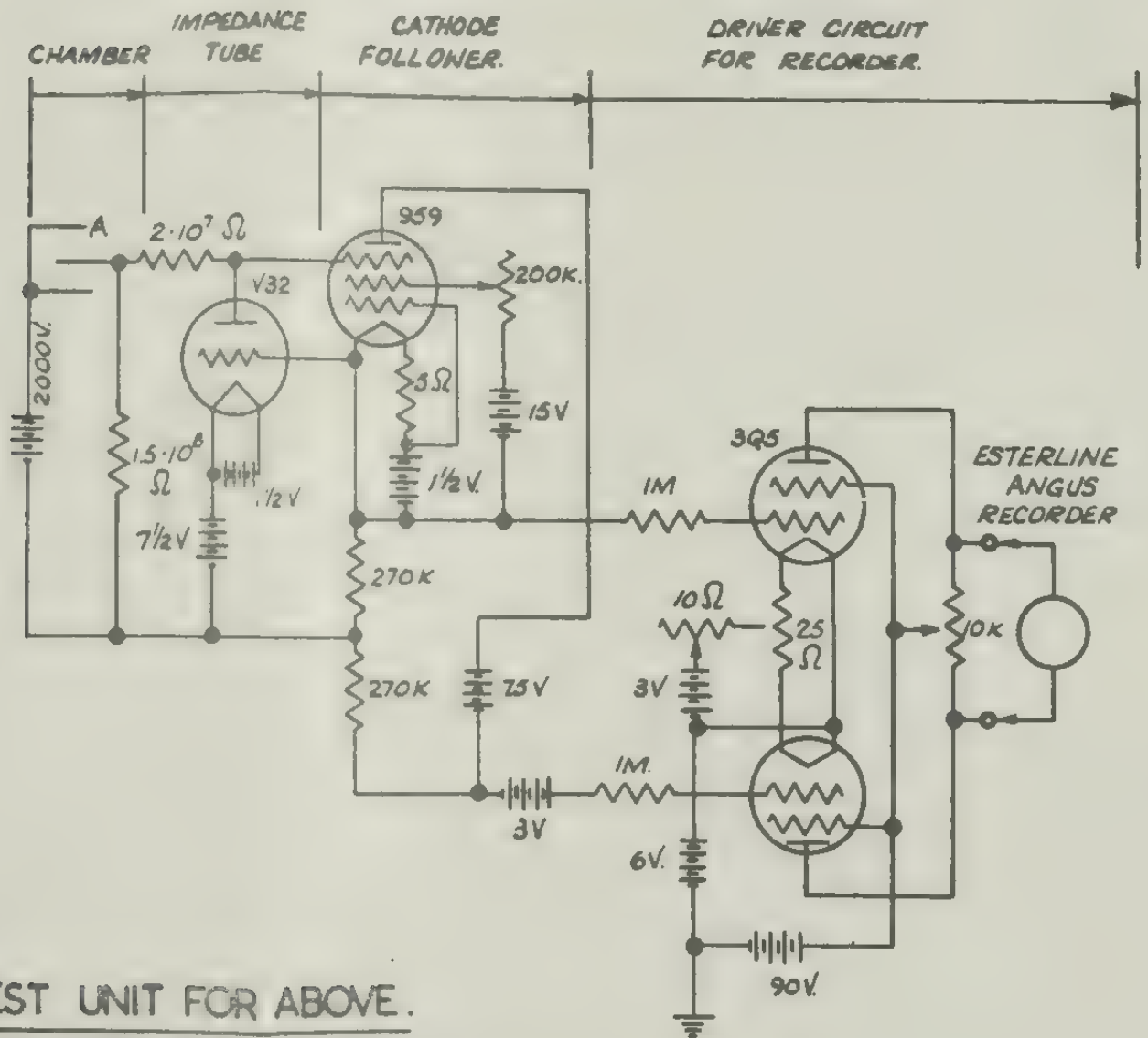


FIG. 1b: TEST UNIT FOR ABOVE.

BY MEANS OF THE METER 'M' AND POTENTIOMETER 'A', A SERIES OF VOLTAGES FROM 1 VOLT TO 250 VOLTS CAN BE APPLIED TO THE HIGH RESISTOR BANK R WHICH HAS A RANGE OF VALUES  $2.5 \cdot 10^9 \rightarrow 10^7 \Omega$ .

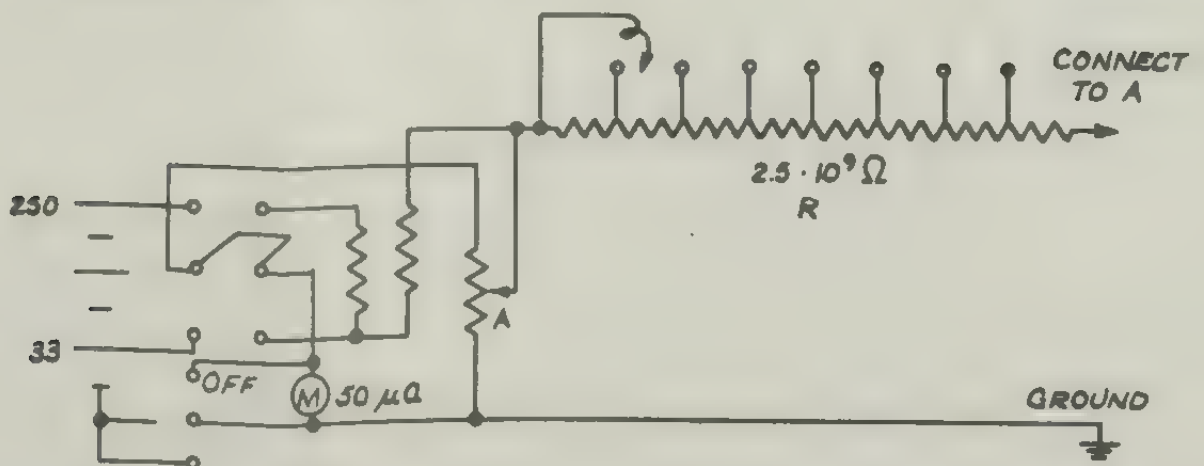
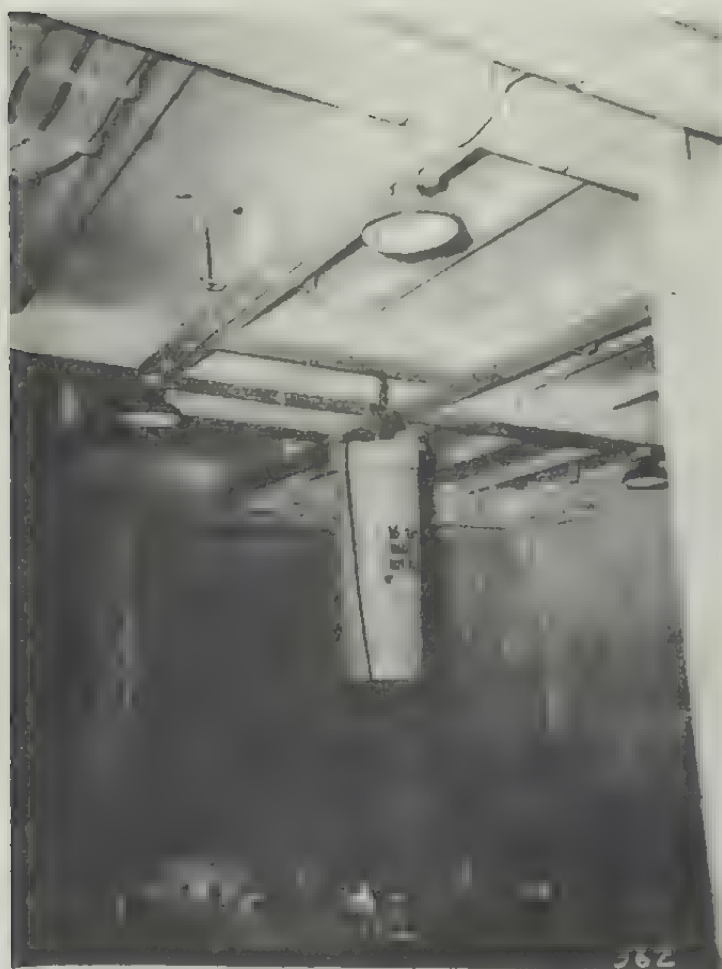


Fig. 2.



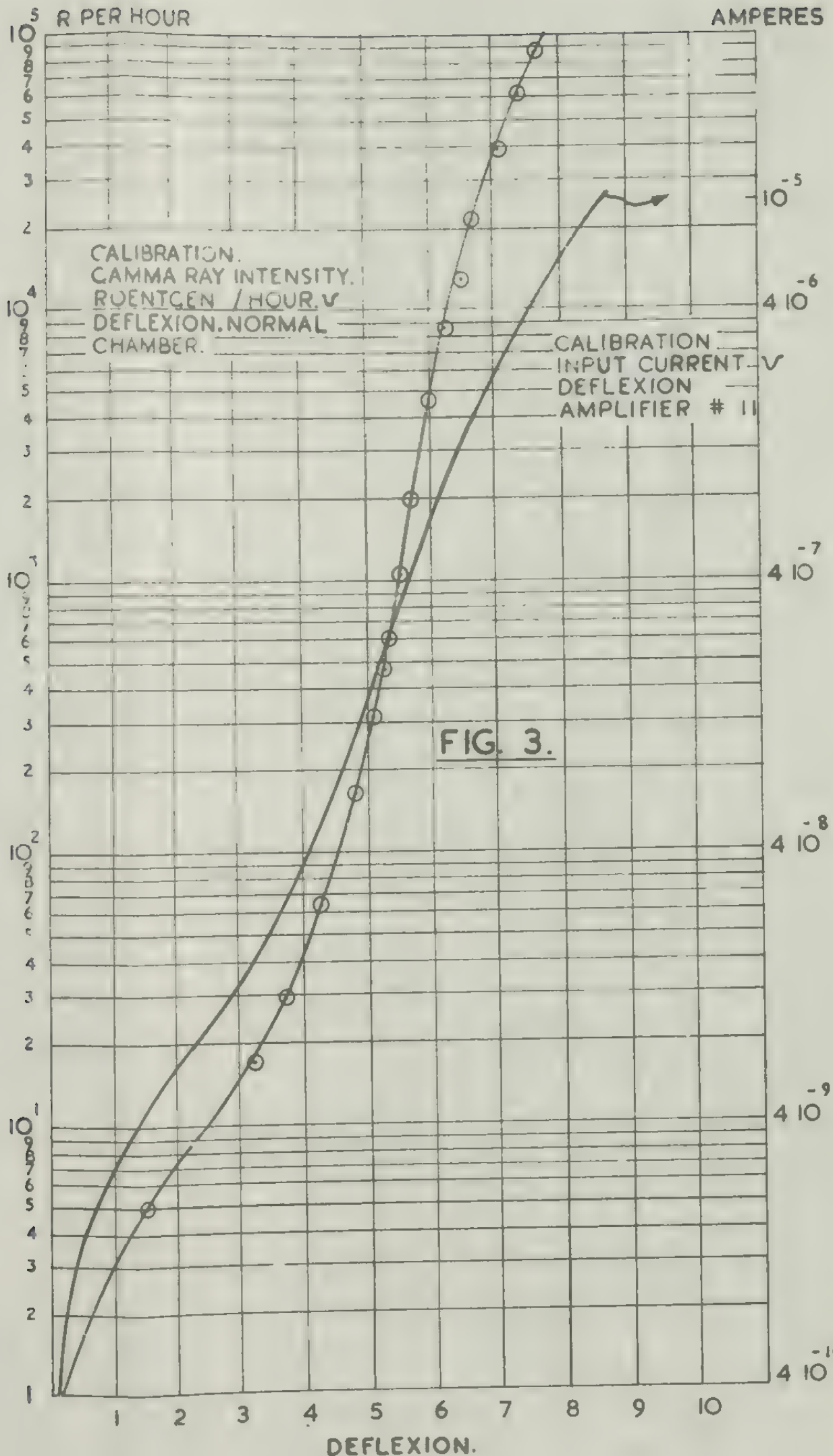
Loading on Pensacola

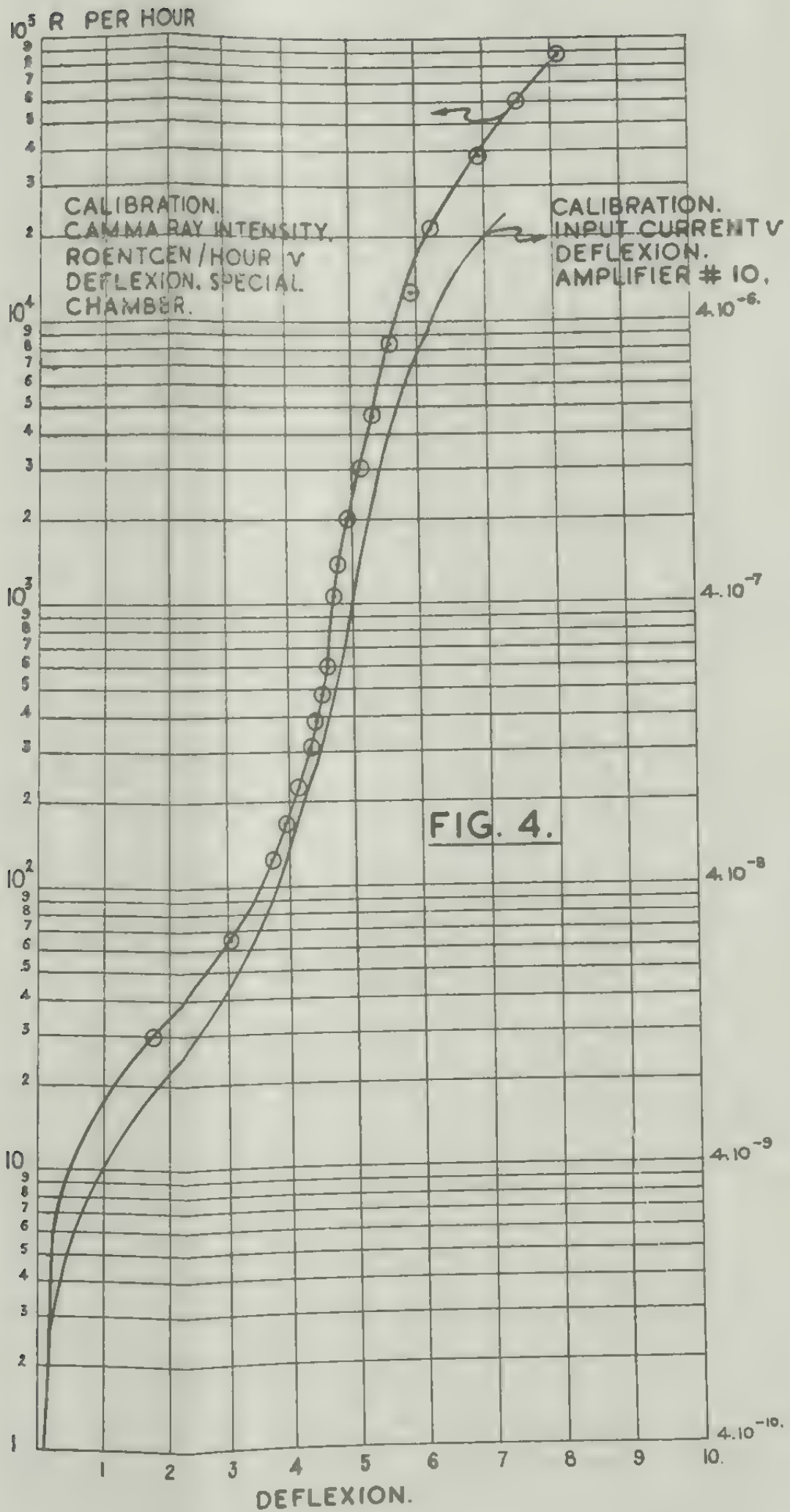


Installation in after troop compartment in A.P.A. 70 (Carteret)

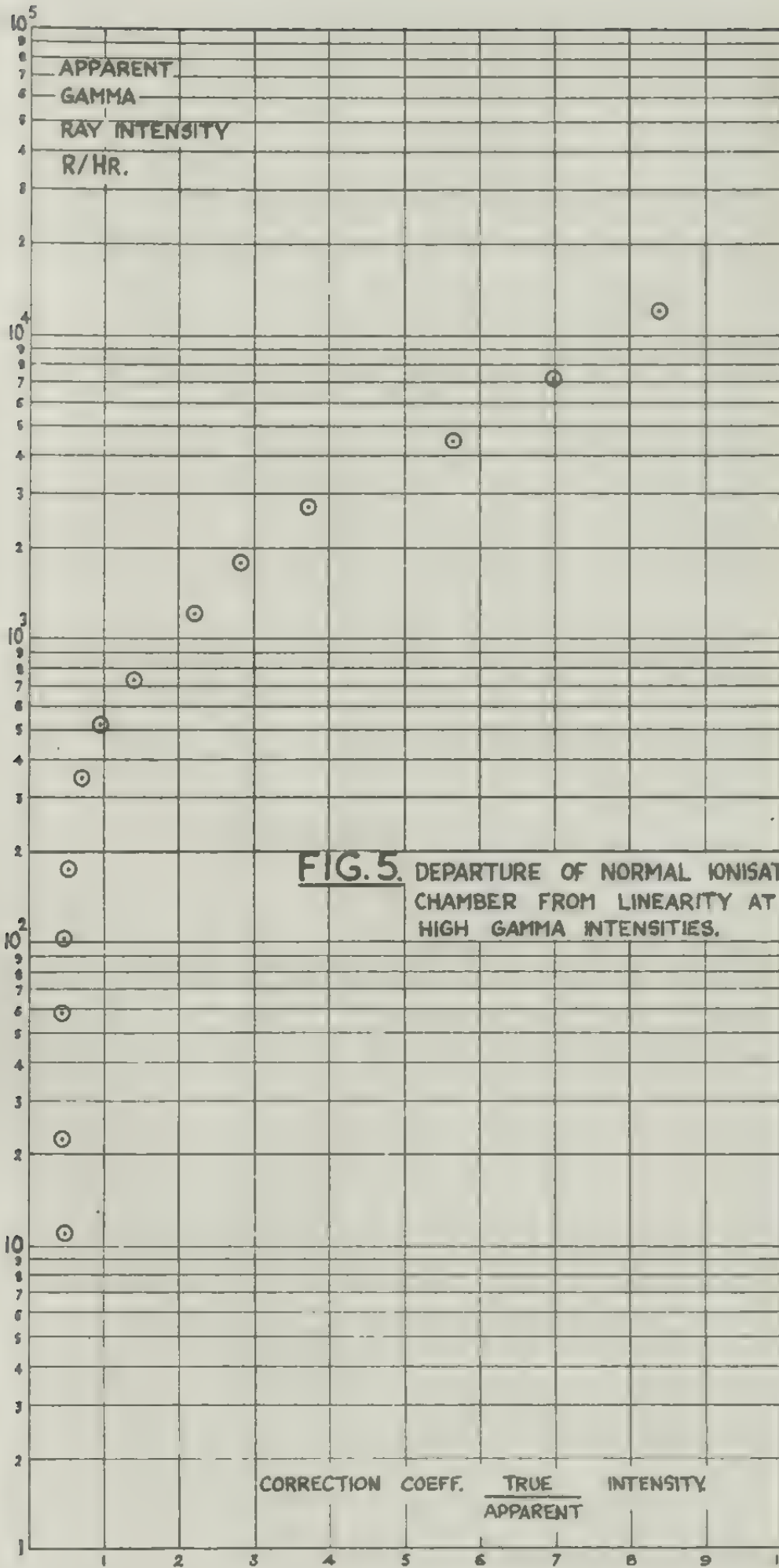


$\frac{dR}{dt}$









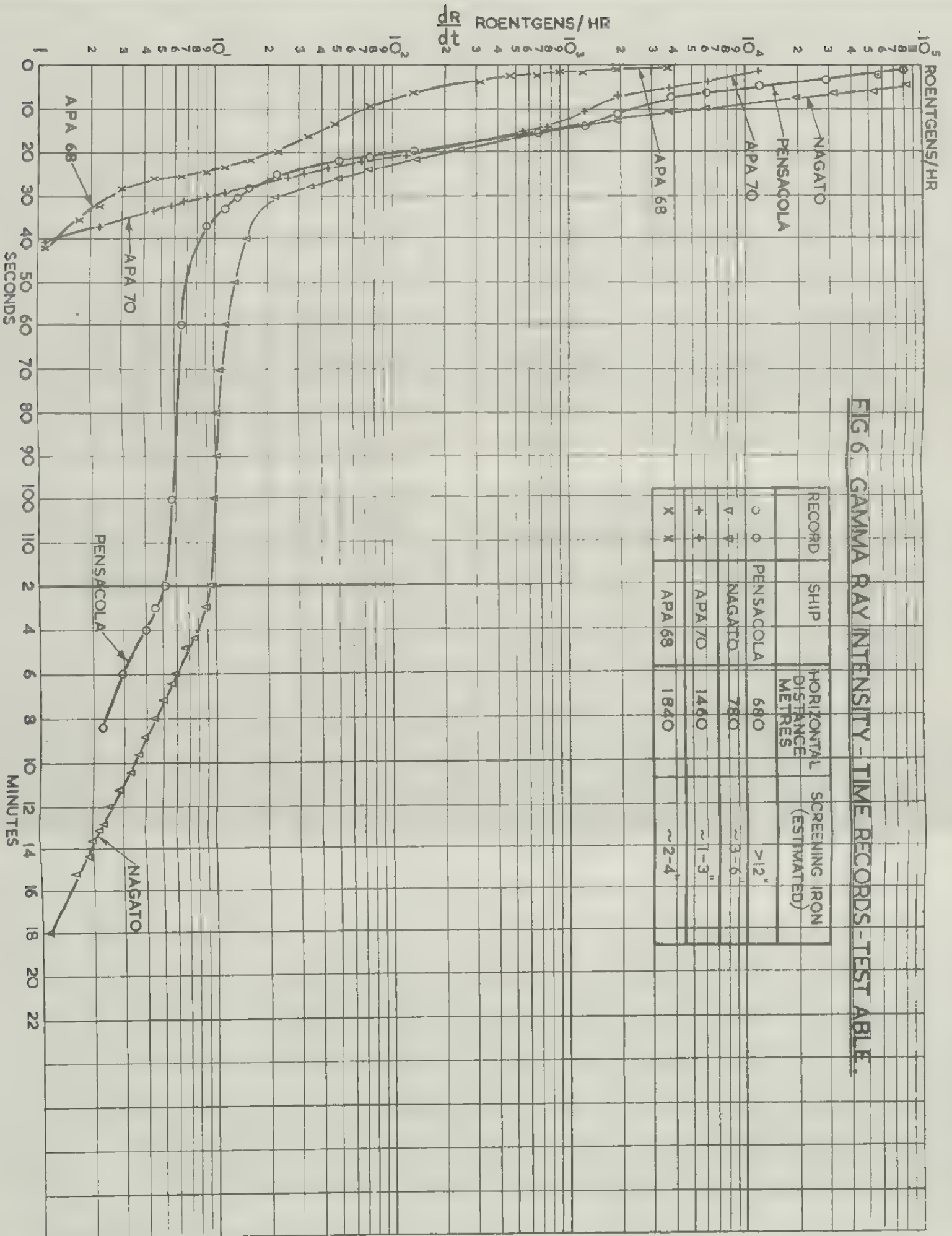
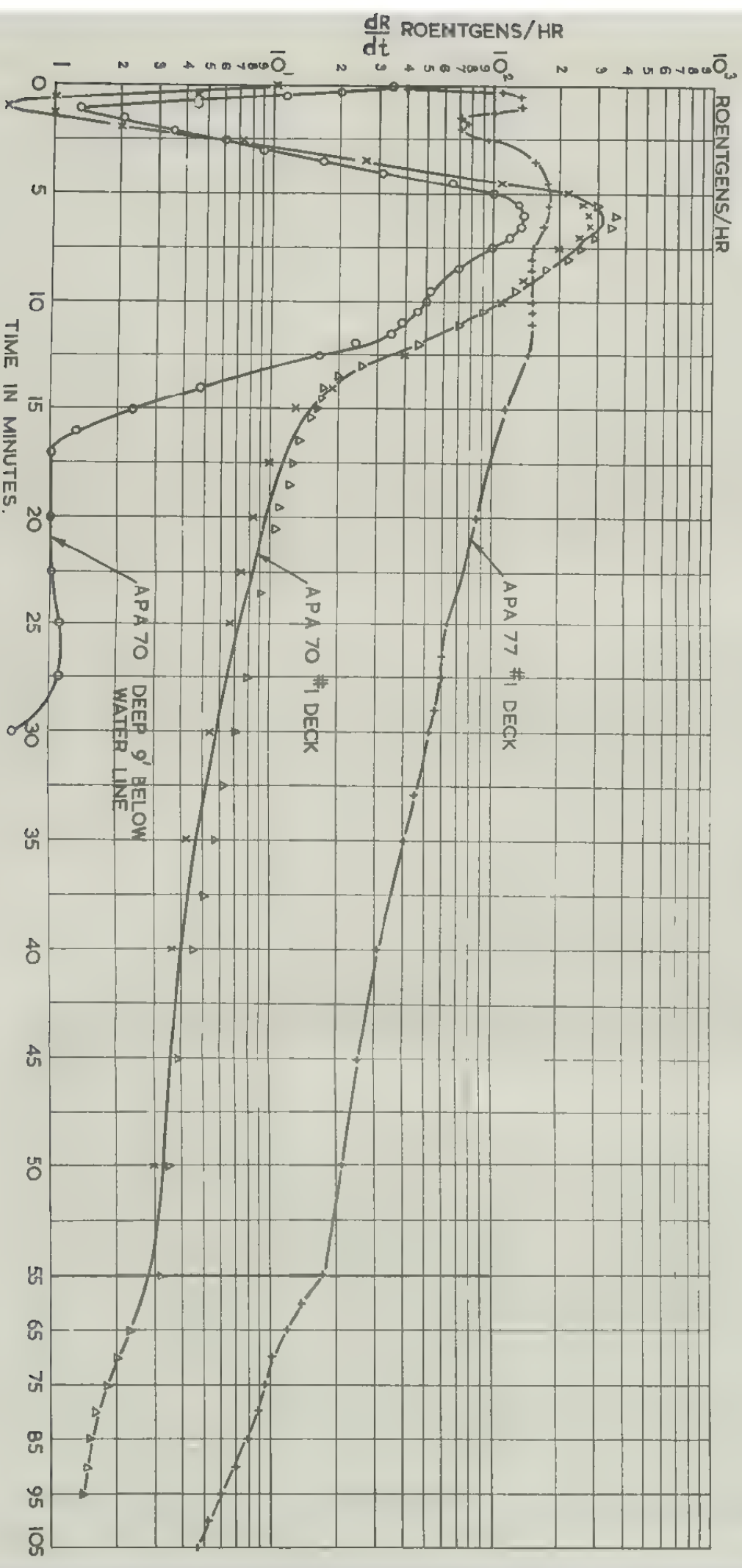


FIG 6. GAMMA RAY INTENSITY - TIME RECORDS - TEST ABLE.



FIG 7. GAMMA RAY INTENSITY - TIME RECORDS - TEST BAKER.

| RECORD | SHIP                 | HORIZONTAL DISTANCE (METRES) | SCREENING IRON (ESTIMATED) | LOCATION IN SHIP                   |                     |
|--------|----------------------|------------------------------|----------------------------|------------------------------------|---------------------|
| + +    | APA 77<br>CRITTENDEN | 1370                         | 1 1/2"                     | #1 DECK FORWARD TROOP HEAD         | SPECIAL CHAMBER     |
| X X    | APA<br>(CARTERET)    | 2740                         | 1 1/2"                     | #1 DECK FORWARD TROOP HEAD         | X X SPECIAL CHAMBER |
| Δ Δ    | "                    | "                            | "                          | "                                  | Δ Δ NORMAL CHAMBER  |
| o o    | APA 70<br>(CARTERET) | 2740                         | 3/8 HORIZONTAL + SEAWATER  | FORWARD STORES 9' BELOW WATER LINE | NORMAL CHAMBER      |



10<sup>5</sup> ROENTGEN/HR

### FIG. 7B. TEST BAKER.

EARLY PART OF RECORD  
SHOWING INITIAL BURST  
SAME SCALE FIG 6.

10<sup>4</sup>  
9  
8  
7  
6  
5  
4  
3  
2  
10<sup>3</sup>  
9  
8  
7  
6  
5  
4  
3  
2  
10<sup>2</sup>  
9  
8  
7  
6  
5  
4  
3  
2  
10<sup>1</sup>  
9  
8  
7  
6  
5  
4  
3  
2  
1

APA 77

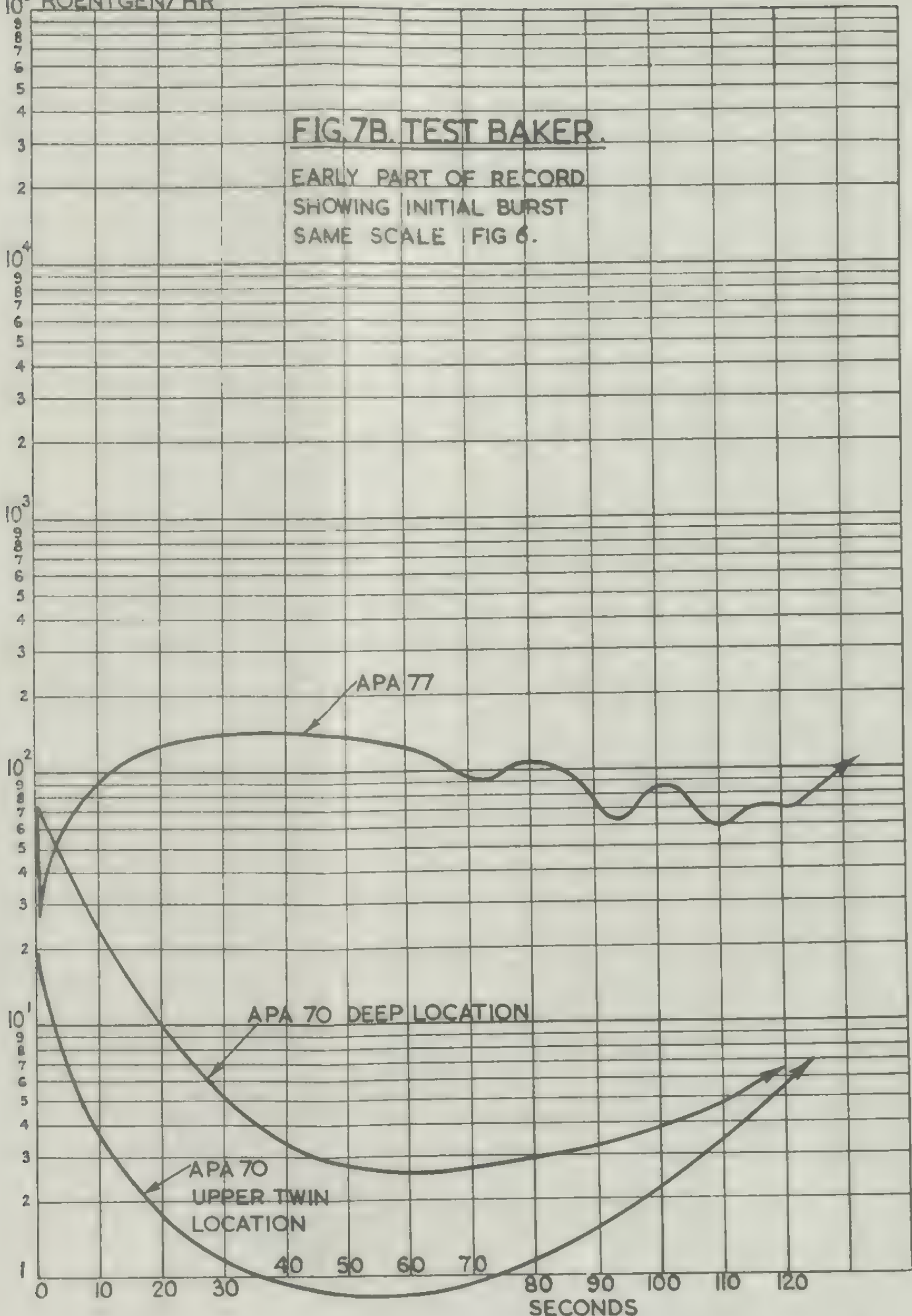
APA 70 DEEP LOCATION

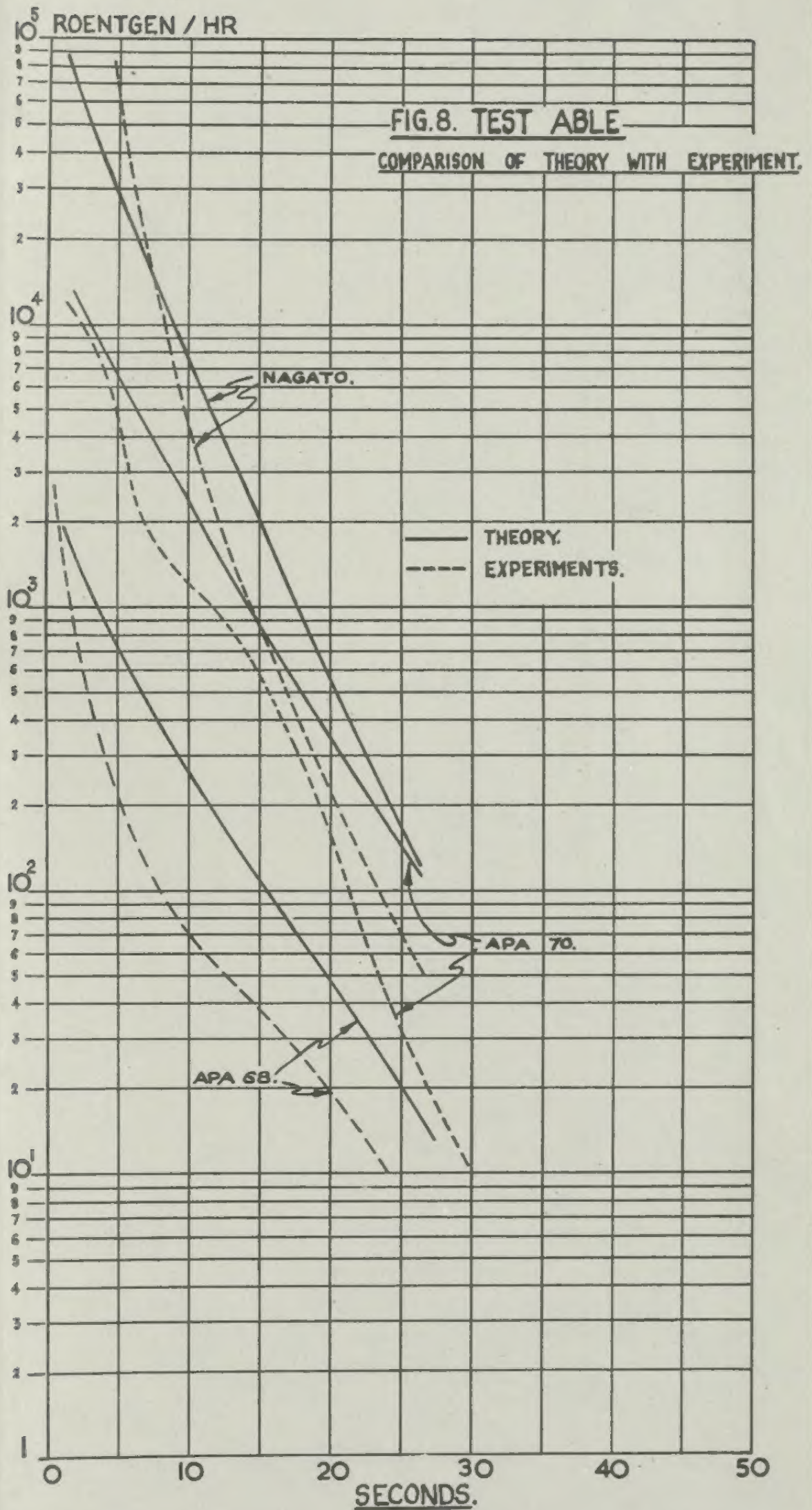
APA 70  
UPPER TWIN  
LOCATION

40 50 60 70

SECONDS

0 10 20 30 40 50 60 70 80 90 100 110 120







# FIG. 9. EVASIVE ACTION CURVE.

SHOWING % DOSE RECEIVED UP TO TIME "t" AFTER BURST

$$y = 100 \int_0^t I(t) dt / \int_0^\infty I(t) dt$$

